Port Fairy Regional Flood Study

Addendum – Sea Level Rise Modelling

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ABBREVIATIONS

AEP	Annual Exceedence Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
GHCMA	Glenelg Hopkins Catchment Management Authority
MSC	Moyne Shire Council
DSE	Department of Sustainability and Environment
IPCC	Intergovernmental Panel on Climate Change
LSIO	Land Subject to Inundation Overlay
FO	Floodway Overlay
VCS	Victorian Coastal Strategy
RFS	Regional Flood Study

1. INTRODUCTION

The Port Fairy Regional Flood Study (RFS) was completed in 2008 (Water Technology 2008). Since its completion, new policies set out in the Victorian Coastal Strategy (VCS) 2008 have provided a framework for the inclusion of sea level rise in long-term planning. In order to match the latest policy directions and available data, some of the outputs of the Port Fairy Regional Flood Study need to be updated.

The Victorian Coastal Strategy 2008 recommended a policy of planning for sea level rise of not less than 0.8 metres by 2100. This recommendation was based on new information arising from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, which projects a sea level rise of 0.18-0.59 metres by 2090-2099, with an additional 0.1-0.2 metres from potential ice sheet melt. Adopting a precautionary approach, the Victorian Coastal Committee recommended that a minimum sea level rise of 0.8 metres (to 2100) be adopted for planning purposes. The VCS also recommended that the combined effects of tides, storm surges, coastal processes and local conditions be considered when assessing the impacts of climate change.

This report forms an Addendum to the report “Port Fairy Regional Flood Study” (Water Technology 2008). The modelling completed for that report has been updated with sea level rise and storm surge information. In addition to the 0.8 m sea level rise recommended by the VCS 2008, a higher sea level rise of 1.2 m was also investigated. The updated modelling includes the effects of riverine flooding, coastal storm surge and projected sea level rise for the 100 year ARI flood and 100 year ARI storm tide. New draft extents for the planning layers LSIO (Land Subject to Inundation Overlay) and FO (Floodway Overlay) are also provided based on the flood modelling outputs. These draft extents may replace the current FO and LSIO if it is decided that sea level rise to 2100 should be accounted for in planning overlays.

The topographic and survey data and the design flood hydrographs used in this addendum study are identical to those in the Port Fairy Regional Flood Study (Water Technology 2008). Refer to Volumes 2 and 3 for details.

In conjunction with this Addendum report, relevant flood maps and GIS layers have been supplied to GHCMA.

2. MODELLED SCENARIOS OF SEA LEVEL RISE AND FLOODING

Two sea level rise cases (0.8 m and 1.2 m to 2100) were applied to the 100 year ARI flood and the 100 year ARI storm tide, giving four modelling scenarios.

Sea Level Rise 1 (SLR1) 100 yr Flood:

- 100 year ARI (1% AEP) flood in the Moyne River and its tributaries
- 10 year ARI (10% AEP) Storm Tide
- 0.8 m Sea Level Rise

Sea Level Rise 2 (SLR2) 100 yr Flood:

- 100 year ARI (1% AEP) flood in the Moyne River and its tributaries
- 10 year ARI (10% AEP) Storm Tide
- 1.2 m Sea Level Rise

SLR1 100 yr Storm Tide:

- No riverine flooding
- 100 year ARI (1% AEP) Storm Tide
- 0.8 m Sea Level Rise

SLR2 100 yr Storm Tide:

- No riverine flooding
- 100 year ARI (1% AEP) Storm Tide
- 1.2 m Sea Level Rise

3. HYDRAULICS

3.1 Model Development and Calibration

The hydraulic model was developed and calibrated as part of the Port Fairy Regional Flood Study (Water Technology 2008). The model was considered to be well-calibrated, with calibration results indicating that the model was "capable of accurately predicting flood and hydrodynamic behaviour at Port Fairy and is appropriate for assessing the level of flood risk to Port Fairy" (Water Technology 2008, Vol. 4, p. 30). See the Port Fairy Regional Flood Study (Water Technology 2008) Volume 4 for details of model development and calibration.

3.2 Design Flood Modelling

3.2.1 Model Boundary Conditions

The boundary conditions for the riverine inflows for the 100 year ARI flood were unchanged from the previous modelling undertaken for the Port Fairy Regional Flood Study. The ocean boundary (water level) conditions were adopted from CSIRO modelling (McInnes et al. 2009) of extreme sea levels under climate change at 2100. For the 100 year ARI flood scenarios the riverine flows were combined with a dynamic ocean boundary condition based on the CSIRO 10 year ARI storm tide at 2100. For the 100 year ARI Storm Tide scenarios the ocean boundary condition was based on the CSIRO 100 year ARI storm tide at 2100. A summary of the boundary conditions for each modelled scenario is given in Table 3-1 below. The ocean boundary conditions are discussed in more detail in Section 3.2.2.

Table 3-1 Boundary conditions for sea level rise scenarios. Ocean boundary conditions are derived from CSIRO (McInnes et al. 2009) levels.

Scenario	Riverine Boundary Conditions	Ocean Boundary Conditions
SLR1 100 yr Flood	1% AEP (100 year ARI) design flow hydrographs for the Moyne River at Toolong, Reedy Creek, Holcombe's Drain and the Murray Brooke catchments	Dynamic boundary condition of CSIRO 10 year ARI storm tide at 2100 1.86 m AHD at peak
SLR2 100 yr Flood	1% AEP (100 year ARI) design flow hydrographs for the Moyne River at Toolong, Reedy Creek, Holcombe's Drain and the Murray Brooke catchments	Dynamic boundary condition of CSIRO 10 year ARI storm tide at 2010 plus an additional 0.4 m sea level rise 2.26 m AHD at peak
SLR1 100 yr Storm Tide	No flow	Dynamic boundary condition of CSIRO 100 year ARI storm tide at 2100 2.09 m AHD at peak
SLR2 100 yr Storm Tide	No flow	Dynamic boundary condition of CSIRO 100 year ARI storm tide at 2100 plus an additional 0.4 m sea level rise 2.49 m AHD at peak

3.2.2 Design Storm Tides

The CSIRO (McInnes et al 2009) have undertaken and reported on storm surge modelling along the Victorian Coast for DSE as part of the 'Future Coasts' Program. The CSIRO report presents predicted extreme sea levels under a number of different climate change scenarios. For this study, Climate Change Scenario 2 was adopted for the prediction of storm tide heights to 2100. Scenario 2 combines a sea level rise of 0.82 m with an increase in wind speed of 19% by 2100. The resulting storm tide levels are a combination of storm surge, tide, sea level rise and increased wind speed effects (primarily storm surge and wave set-up).

Table 3-2 CSIRO (McInnes et al. 2009) Storm Tide Statistics

AEP (%)	ARI (1 in Yr)	CSIRO 2009 Port Fairy Storm Tide Levels (m AHD)	Components of Storm Tide			
			Storm surge	Tide (m)	Sea level rise (m)	Increased wind speed effect (m)
10	10	1.86	0.56	0.27	0.82	0.21
1	100	2.09	0.60	0.45	0.82	0.22

The levels above were used for modelling scenario SLR1 (0.8 m Sea Level Rise). For SLR2 (1.2 m Sea Level Rise) an additional 0.4 m sea level rise was added to the CSIRO Storm Tide levels.

In order to develop the dynamic storm tide boundary, a 72 hour period storm was assumed. This is consistent with typical storm surge durations observed along the Victorian coast. A sinusoidal storm surge curve was superimposed on a typical predicted tidal signal and sea level rise of 0.8 m and 1.2 m. The peak of the surge and tide were timed to coincide and produce the design sea surface elevations listed in Table 3-2. Figure 3-1 shows the resulting ocean water level time series.

The use of a dynamic sea level boundary provides a more realistic prediction of flood levels within Port Fairy and the Moyne River estuary. A constant sea level at the ocean boundary has been estimated to conservatively elevate peak flood levels in the Belfast Lough by around 100 mm. The assumption of coincident peak flood flow and storm surge height could still be considered conservative, however due to uncertainties in adopting an alternative arrangement; this is considered a reasonable approach. The historical coincidence of storm surge and flooding is discussed below in Section 3.2.3 of this report.

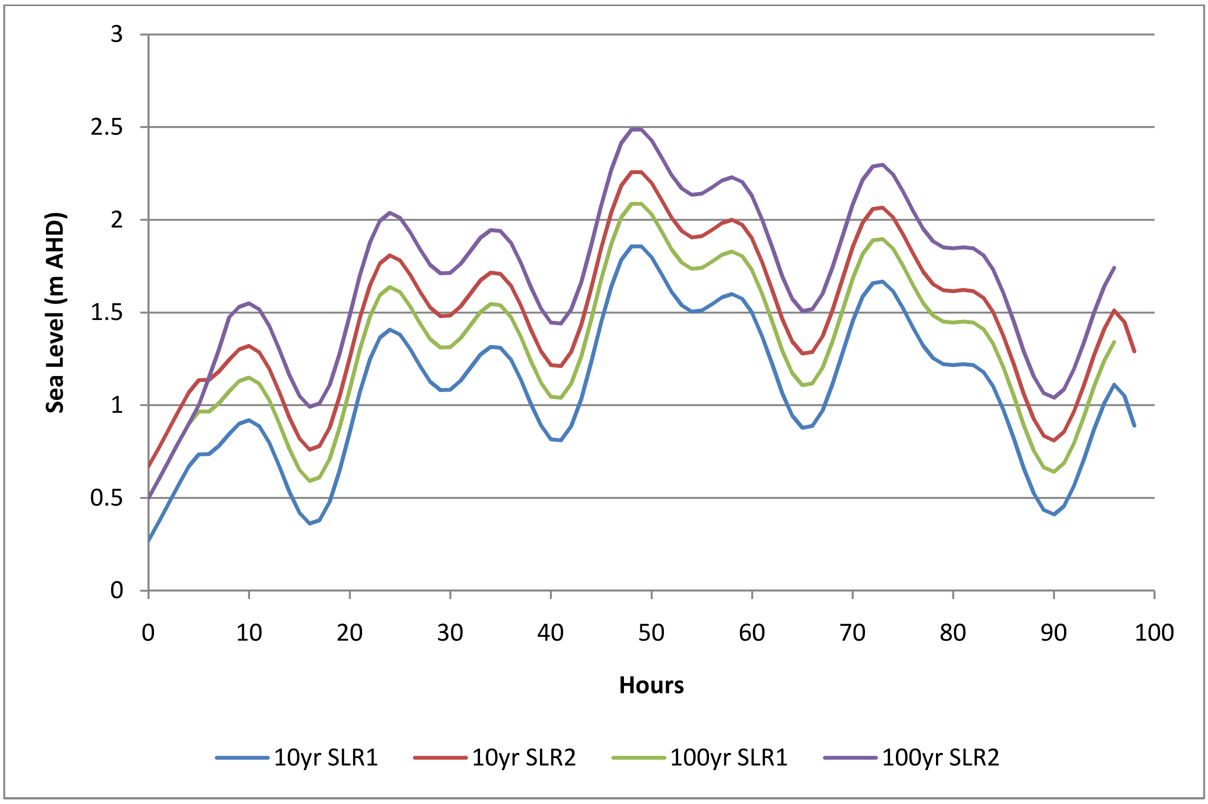

Figure 3-1 Dynamic storm tide boundary for 10 year and 100 year ARI events (SLR1 - 0.8 m Sea Level Rise, SLR2 - 1.2 m Sea Level Rise)

In previous modelling for the Port Fairy RFS (Water Technology 2008), ocean boundary conditions were based on an analysis of recorded sea levels at Portland over a 24 year period. A distribution fitted to the recorded levels gave estimates of design sea levels at Port Fairy. A comparison of the CSIRO (McInnes et al 2009) and Water Technology design sea levels (without climate change effects) is provided in Table 3-3 below. The newer CSIRO levels are in general agreement with the Water Technology estimates used in the Port Fairy RFS.

Table 3-3 Comparison of storm tide statistics (without climate change effects)

AEP (%)	ARI (1 in Yr)	CSIRO 2009 Port Fairy Levels – Tide + Storm Surge (m AHD)	WT 2008 Portland Level Analysis – Tide + Storm Surge (m AHD)
10	10	0.83 ± 0.08	0.93
1	100	1.05 ± 0.12	1.07

3.2.3 Rationale for Combination of 10 year ARI Storm Tide with 100 year ARI Flood

In the Port Fairy RFS (Water Technology 2008), the 1% AEP design flood was modelled in conjunction with the 10% AEP storm surge, as recommended in Floodplain Management in Australia: Best Practice Principles and Guidelines (SCARM Report 73, 2000).

Water Technology undertook detailed analysis of sea level records and flow gauging for the Port Fairy RFS, which is detailed in Section 4.5 Volume 4, Hydraulics report (Water Technology, 2008). This analysis compared recorded sea levels at Portland with peak annual gauged flows for the

Moyne River at Toolong, over the period 1982 to 1998. This record covered a range of annual floods from minor through to approximately a 20 year ARI.

Recently, additional sea level records from Portland have become available from DSE Floodplain Management Unit for 1946 that had not been previously identified. This allowed a comparison of the extreme flood conditions of March 1946 with recorded sea levels to ascertain if there was any correlation between flood peak and storm surge for that event.

Hourly sea levels at Portland were digitised and then adjusted (-0.51 m) to reduce them from chart datum to mean sea level (effectively AHD). A harmonic tidal analysis was performed to extract the main tidal constituents. These compared well with those from the current National Tide Tables, providing confidence that the water level records from this period are reliable. Tidal predictions were then made over the period of record and subtracted from the recorded levels in order to compute the estimated tidal residual (storm surge).

Figure 3-2 below shows the 1946 predicted flow hydrograph along with daily rainfall data for Hawkesdale, recorded sea level at Portland, predicted tide and computed residual. This plot clearly shows there was virtually no storm surge impact at Portland at the time of the 1946 flood. Due to proximity and the open coastline between Portland and Port Fairy, it can be reasonably assumed that no significant storm-surge occurred at Port Fairy over the same period.

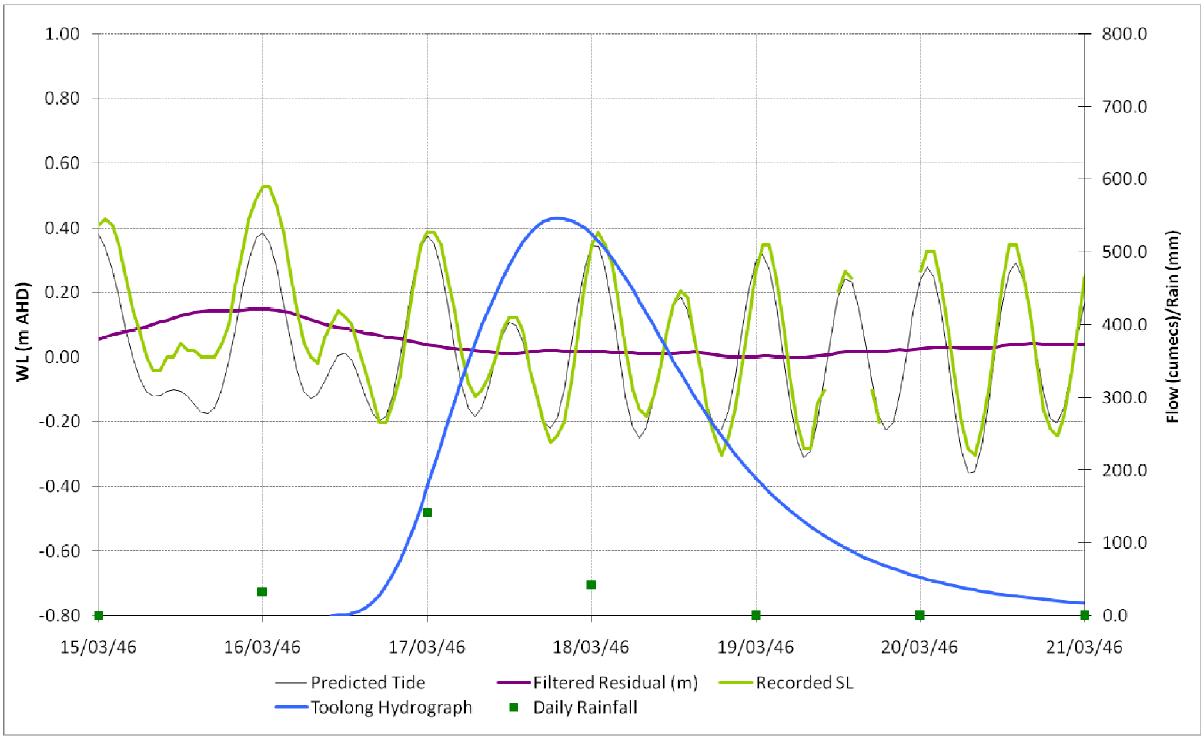

Figure 3-2 1946 Comparison of Portland tide and Moyne River flow

The results of the 1946 flood and tide analysis are combined with the previous 1982-1998 data and plotted in Figure 3-3 below. This suggests that the observed tide residuals (storm surge) for annual flood peaks are commonly less than a 1year ARI (around 0.4 m).

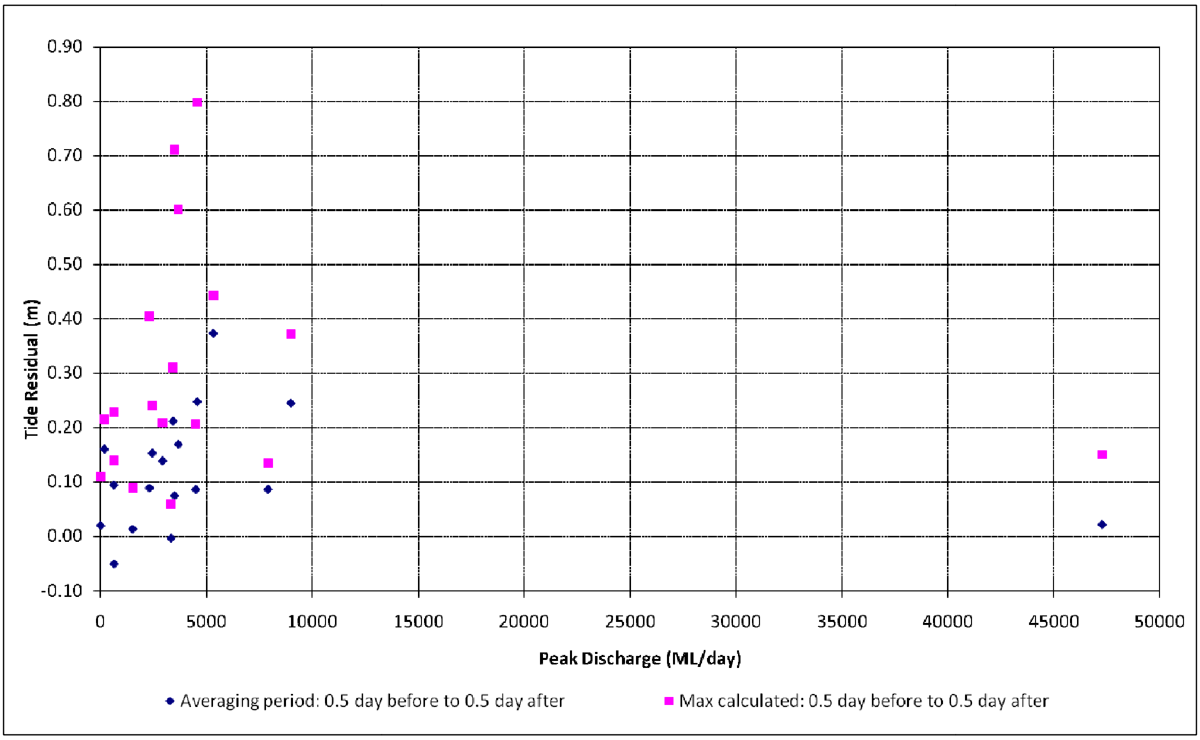

Figure 3-3 Correlation between flood peaks and storm surge (tide residual)

Based on the above data the previous combination of 100 year ARI (1% AEP) flood with a 10 year ARI (10% AEP) sea state was adopted for the present sea level rise scenarios. Whilst this could be argued to be conservative when compared to the observed data, in a practical sense there is not a significant difference between say a 1 year ARI and 10 year ARI sea level as the probability curve for these events is relatively flat.

The adoption of this combination is also consistent with the 2008 flood study, best practice guidelines for floodplain management in Australia (SCARM Report 73, 2000) and other recent studies in Victoria.

3.2.4 Simulation Results

The effects of sea level rise on the 100 year ARI flood and storm tide extent are shown in Figure 3-4 and Figure 3-5. The effect of sea level rise is greatest in Belfast Lough and the narrow entrance downstream of Gipps Street Bridge, and decreases upstream. The 100 year storm surge has a smaller extent and depth of inundation than the 100 year flood, except for the area within about 500 m of the mouth of the Moyne River (downstream of the footbridge).

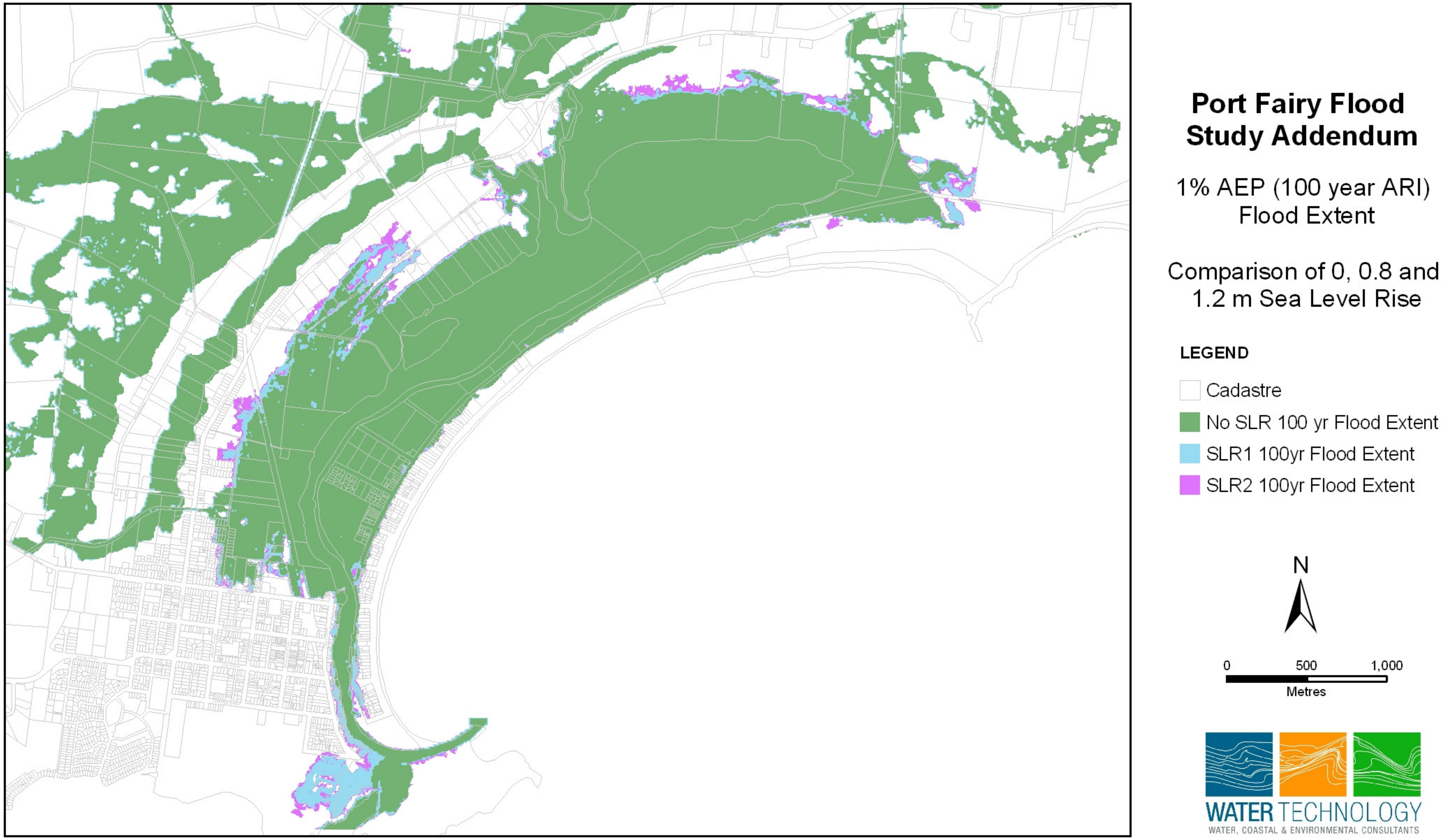

Figure 3-4 **Comparison of 100 yr ARI flood extent with 0 m, 0.8 m (SLR1) and 1.2 m (SLR2) sea level rise**

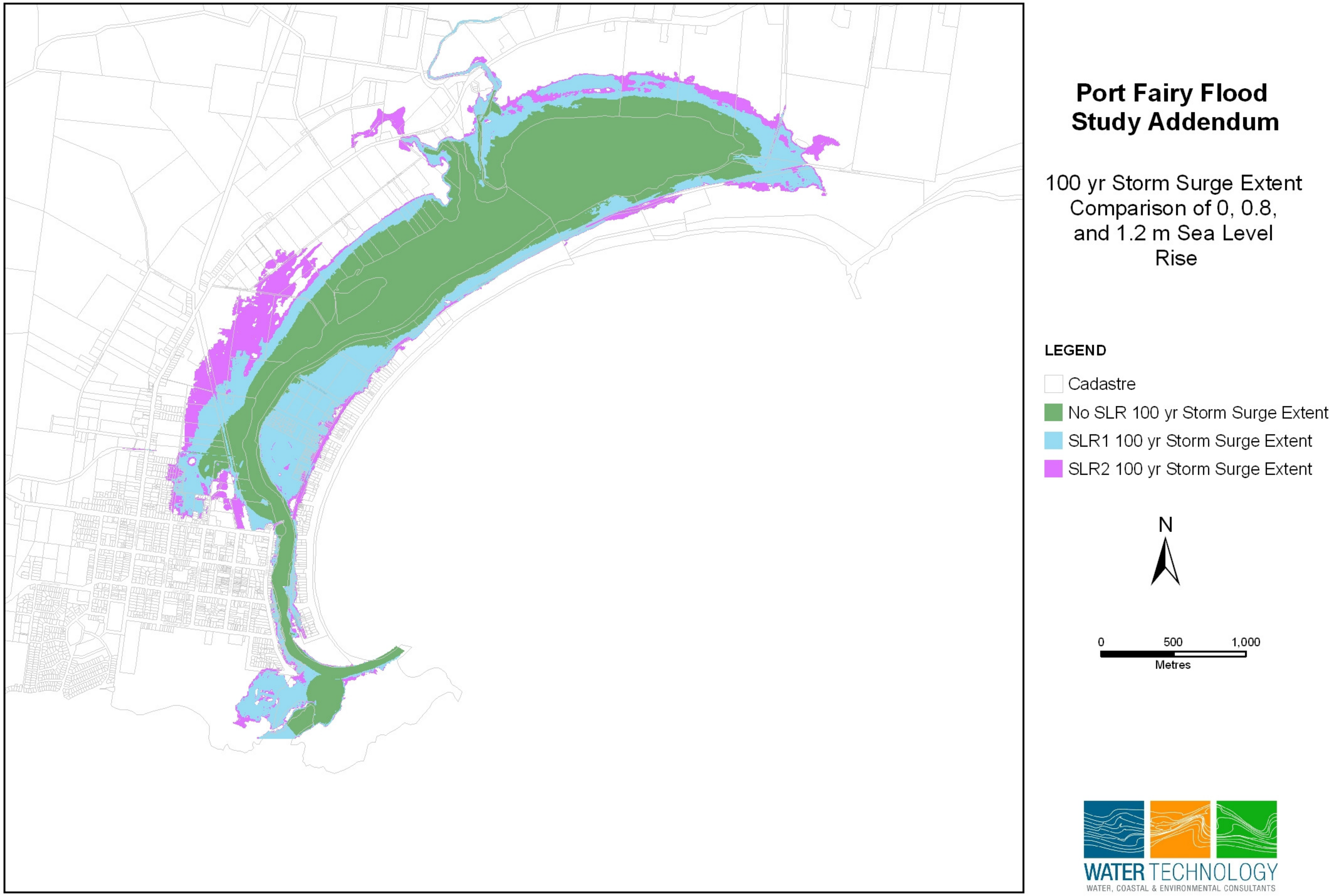

Figure 3-5 Comparison of 100 yr ARI storm surge extent with 0 m, 0.8 m (SLR1) and 1.2 m (SLR2) sea level rise

4. MAPPING

4.1 Flood Inundation Maps

A1 flood inundation maps for the four modelled scenarios have been provided including flood depth and water surface elevation contours.

4.2 Flood Mapping for Land Use Planning

Draft flood-related planning overlay delineations for Floodway and Land Subject to Inundation Overlays were provided as part of the Port Fairy Regional Flood Study (Water Technology 2008). The delineation of these planning overlays may need to be updated to include 0.8 m sea level rise, in line with the Victorian Coastal Strategy 2008. It has not yet been decided definitively whether flood levels and extents at 2100 should be used for declarations and planning scheme amendments. Draft overlay delineations have been developed for the Land Subject to Inundation Overlay (LSIO) and the Floodway Overlay (FO) accounting for sea level rise to 2100. These draft overlays may be used to replace the previous overlays if it is decided that the projected 2100 flood extents are to be used in the planning scheme.

4.2.1 Land Subject to Inundation Overlay (LSIO)

The Land Subject to Inundation Overlay (LSIO) identifies land subject to inundation by overland flow, in flood storage or in flood fringe areas affected by the 1% AEP flood. The proposed LSIO extent was derived from the modelled extent of the 1% AEP flood at 2100 (incorporating 0.8 m sea level rise) with minor smoothing of extents and infilling of minor holes (islands).

4.2.2 Floodway Overlay (FO)

The Floodway Overlay (FO) identifies waterways, main flood paths, drainage depressions and high flood hazard areas. The NRE's "Advisory Notes for Delineating Floodways" (Edwards, DNRE 1998) provide a guide to the identification of floodways. Three criteria were used to determine the extent of the Floodway:

- Flood Frequency – areas inundated by the 10% AEP (10 year ARI) Flood
- Flood Hazard – Areas defined as "Floodway" in Figure 4-1 using the 1% AEP (100 yr ARI) flood velocity and depth.
- Flood Depth – Areas with maximum flood depth greater than 0.5 m in the 1% AEP (100 yr ARI) flood.

The three extents resulting from each of the criteria were enveloped to give the final Floodway extents.

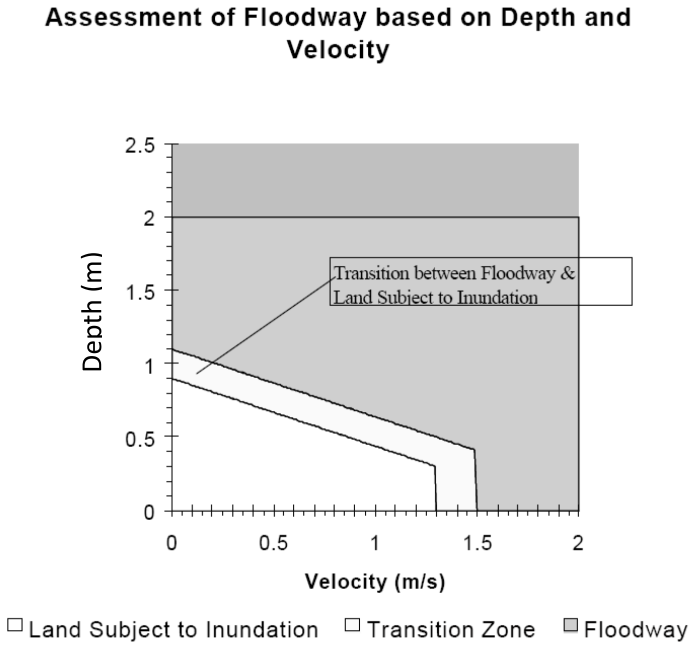

Figure 4-1 Floodway overlay flood hazard criteria (Edwards 1998, p. 10)

4.2.3 Proposed Overlay Delineation

The draft extents of the Land Subject to Inundation Overlay and the Floodway Overlay (incorporating 0.8 m sea level rise) were prepared according to the criteria in Sections 4.2.1 and 4.2.2. The draft extent of the LSIO and FO are displayed in Figure 4-2.

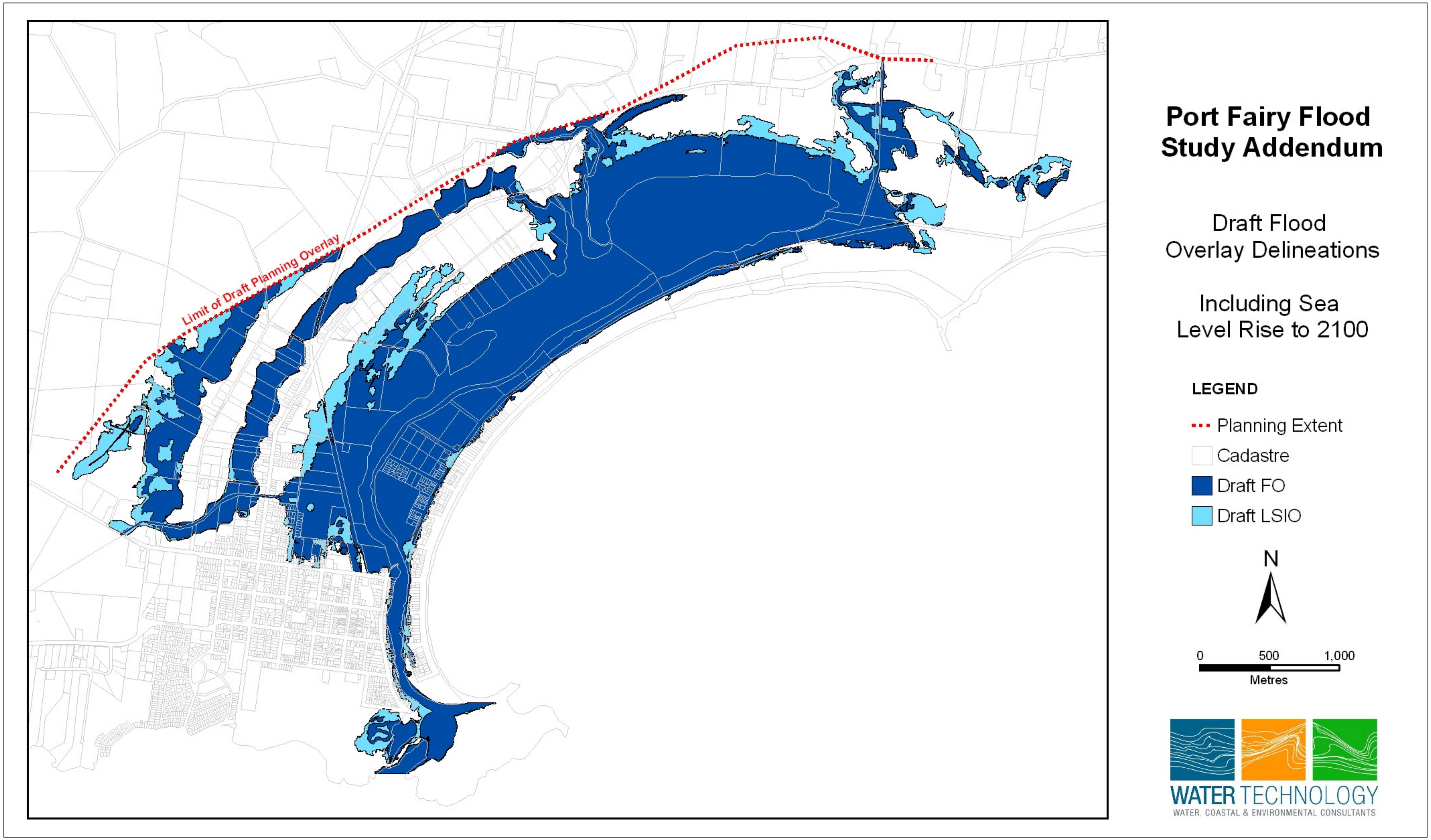

Figure 4-2 Draft Floodway Overlay (FO) and Land Subject to Inundation Overlay (LSIO) delineation for the inclusion of sea level rise to 2100 in planning overlays

5. REFERENCES

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